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Design of the Auto Electric Power Steering System Controller

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Abstract

The automobile electric steering system is a servo control system. This paper introduces the basic composition of the electric power steering system, and put forward the reasonable design solutions of the soft hardware and the correction methods of controller, given the main technology index of the controller. According to the performance requirements of cars steering system, make the relevant control strategy of the electric power steering system and through the design of related software and hardware to realize this control strategy and it can control each link of the automobile steering process. In order to verify the feasibility of the control strategy, comparison experiments are carried out on a vehicle equipped with the developed EPS and the imported EPS, respectively. The results indicate that the developed EPS has similar performance with the imported one. The developed EPS not only works smoothly, but also has proper steering performance, thus can be equipped on passenger cars.

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Keyword: Electric power, steering system, servo system, controller;

1. Introduction

There are three kinds of automobile steering system, for mechanical and hydraulic, and electricity-powered. At present, most car use rotary valve hydraulic power steering system but parts of cars start to use electric power steering system and it has obvious effect in energy saving. The current automobile electric power steering system (referred to as EPS) has significant advantage: energy-conserving and environment-protective; easy to modular design and installation; convenient in maintenance, easy to adjust and testing. In addition, some new technologies such as automatic driving, automatic parking, also require the application of EPS. Therefore, the automobile electric power steering system has good

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application prospect. The dynamical characteristics of the Electric power steering system (EPS) is the rule that the power (moment) along with the car movement status (steering wheel hand power and the speed) changes, its power performance mainly include steering system's stability, tracking and anti-jamming. Poor power performance will make the steering wheel appeared to dithering, power lag and so on. It easily causes the driver fatigue and driving out of control, which may lead to traffic accidents. Therefore, the EPS design goal is to strengthen the stability, tracking and immunity.

2. The electric power steering system

The automobile electric power steering system (EPS) is made up of two parts: mechanical structure and electronic unit. The mechanical parts include the steering wheel, steering column, torsion bar, reduction gears mechanism, power steering motor, gear and rack, etc.; Electronic parts include the steering wheel torque sensor, the wheel speed sensors and electronic ECU etc. The automobile electric power steering system structure is as shown in figure 1 below:

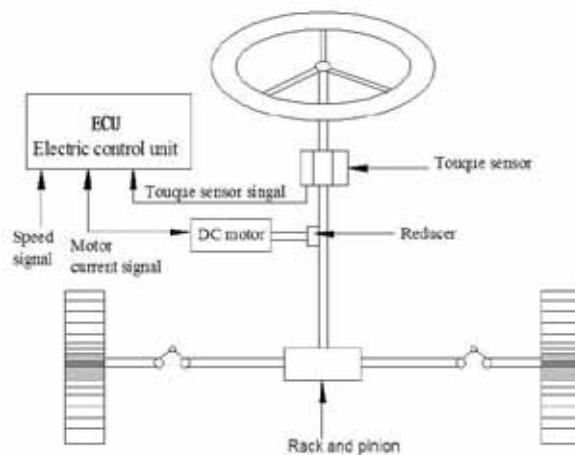


Fig. 1. Automobile EPS system structure diagram

This system is a position servo system, and its working process is: when the steering wheel turns, the torque sensor which is installed in the steering wheel axle sleeve detect the torque that the steering wheel produces. And it will make the torque converter for voltage signal to form a torque signal. The A/D module which in the controller makes the tested torque signal converts for the digital quantity. The current flows through the power motor will be collected back, form the feedback current signal feedback to the controller. According to the torque signal and feedback current signal, the controller will calculate the size of the booster current and it will drive the power motor through the PWM control mode. Speed signal detection is one of the most important parts. With different speed, the power curve will also change correspondingly: the higher the speed, the smaller the power. When it reaches a certain speed, the power will stop, which make the driver have good road feeling. This article focuses on the design of the controller.

3. The design for the hardware of the controller

3.1. power vary circuit

This power motor is a brush dc motor, its main parameters are: the rated voltage is 12 V, rated current is 30 A, rated speed 1180 RPM. In the power motor control, we use the dc pulse width modulation (PWM) technology. This system uses the fixed frequency width way, the modulation frequency produced by MCU is 21 KHz. The main advantages of the PWM speed are that: (1) the main circuit is simple, it needs less power components; (2) due to its high switch frequency, only depend on the filtering action of the armature inductance, we can obtain the smooth dc current, and its speed adjusting performance is good; (3) switching devices work only in switch condition, main circuit consumption is small, the devices have a high efficiency. Power varies circuit shown in figure 2.

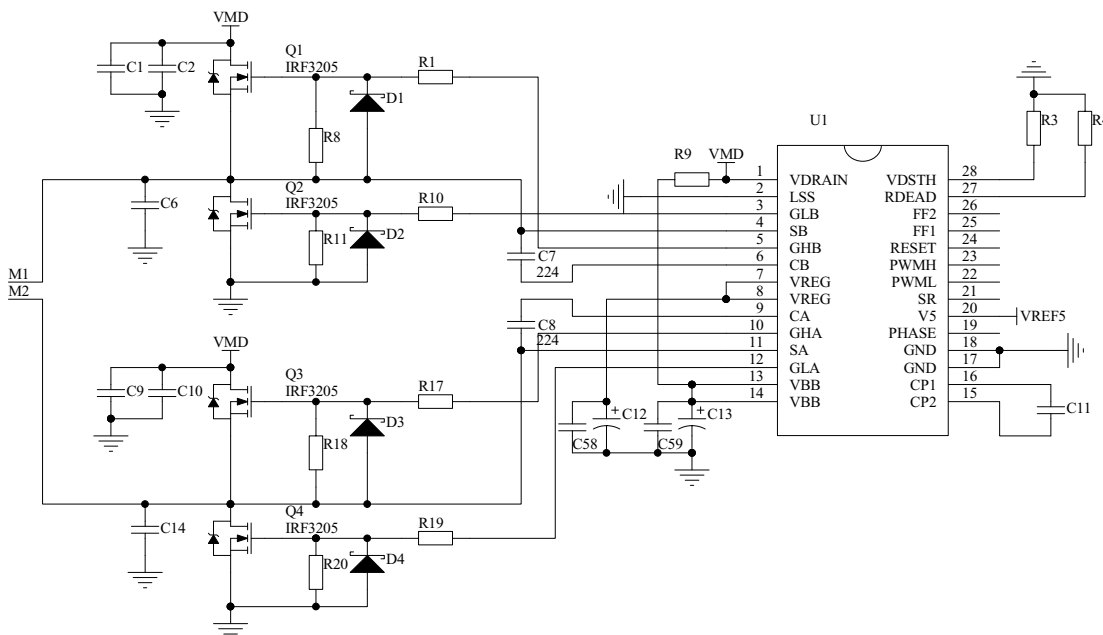


Fig. 2. Power varies circuit

The main circuit consists of four IFR3205 MOSFET as power tube which constitute a reversible bridge type (type H) PWM vary circuit. Power tube Q1 and Q4 are as a group, Q2 and Q3 are as for another group, which to work by turns. Here, Q3 and Q4 are just to control the direction of the motor. Their conduction/shut off are controlled by ordinary export; The Q1 and Q2 are for speed control, their conduction/shut off are controlled by the PWM signal. To prevent the same bridge road Q1 and Q3, Q2 and Q4 appear at direct type phenomenon, we design that the same bridge road has opened delay circuit, in addition, there are interlock measures between the two groups. Although the MOSFET already has a leak source diode, it can play a role in follow current, but in bridge type circuit, the diode has the reverse recovery time problem, when the motor reverse, the leak source gap between Q1 and Q2 is very large; it is easy to breakdown and makes the bridge legs direct type. Therefore, we use the D1, D2, D3, and D4 as four fast recovery diodes and make the M1 and M2 connected motor in the design.

3.2. The overall framework for hardware circuit

The hardware circuit of the electric power steering system mainly includes these following modules: the microcontroller, power circuit, signal processing circuit, dc motor power driving module, fault diagnosis and display module, speed sensor, torque sensor, engine ignition signal, access processing circuit for current and current sensor etc. The logical frame of the EPS system hardware is as shown in figure 3 below.

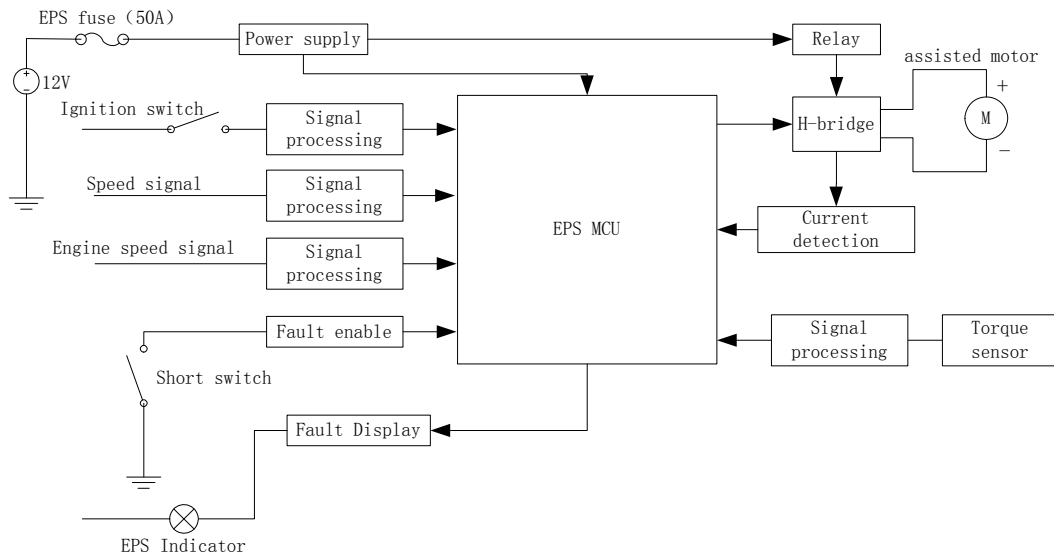


Fig. 3. Composition diagram for EPS control system

There are some shows in the hardware design: (1) in order to improve the reliability, we use two independent input road of circuit. In one road, the numeration chip records pulse number automatically. In the other road, two HSI ports of the MCU complete that work; (2) set a hardware watchdog to blockade PWM output; (3) in the design of PCB, we need to pay attention to the separation of the strong and weak electricity and electromagnetic compatibility. (4) In the structure layout, we need to note the heat dissipation of the power components.

4. Control strategy

4.1. The mathematical model of the system

The main index of the servo system is tracing performance. These output response performance of power, flexibility and accuracy mainly reflect tracing performance. Torque sensor tests the torque between the steering wheel and the runner and according to the size of torque signal, we drive the dc motor by the way of PWM and detect the current of the motor as the feedback quantity. The principle structure is as shown in figure 4 shows.

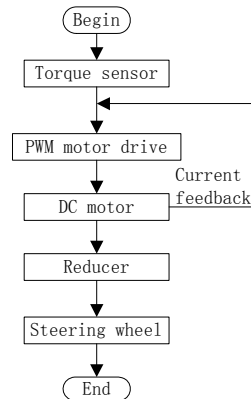


Fig. 4. The theory structure of the servo system

The corresponding transfer function for the links above is: PWM power amplifier $\approx \frac{K_1}{T_1 s + 1}$,
 Moto = $\frac{K_2}{(T_d s + 1)(T_m s + 1)}$, reducer = $\frac{K_3}{s}$, angle-feedback = K_4 , The transfer function of the system is simplified to:

$$G(s) = \frac{K_\theta}{s(T_\mu s + 1)(T_m s + 1)} \quad (1)$$

In the formula: $K_\theta = K_1 K_2 K_3 K_4$ are the magnification factors; $T_\mu = T_1 + T_d$ is the sum of time constant, among them T_1 is the delay time for PWM transformation; T_d is the electromagnetic time constant of the motor; T_m is electromechanical time constant of the motor.

4.2. Correction methods

Use PID correction, the transfer function is: $G_C(s) = K_p \left(1 + \frac{1}{T_i s} + T_d s\right)$ (2)

In the formula: K_p is proportional coefficient; T_i is integration time; T_d is differential time.

The basic correction method is: according to automatic control principle, take the zero of the regulator and the pole of the control object in cancellation, make the open-loop transfer function of the system become the typical I or the typical II system, then according to the best engineering parameters, we design the scheme. Then we determined the PID parameters primarily (we can also get it according to the mathematical model with MATLAB simulation directly), and then dispersing processing, transfer to the discrete PID and then write the experimental program, to complete the final setting by the field test.

In practical application, we use the integral separation PID correction. When the deviation is larger, we use the PD correction; when the deviation is lesser; we use the PID correction, and limit the integral. In

addition, we also Set a threshold range, when the deviation enter the range, it does not correction. This convenient variable structure of the control mode reflects the advantages of digital controller.

5. Software Design

Using C language to program, and modular design method. According to the functions, it can be divided into the main program and interrupt service routine. Main program is for data acquisition and processing to meet the high sampling rate requirements; various control tasks are completed via interrupt manner, such as serial communications, interrupt input of reflecting the steering wheel rotation information, watchdog timer set to the number, timing PWM output, timer fault diagnosis. Figure 5(a) is the main program flow chart. Figure 5(b) is for the regular PID correction and PWM output interrupt service routine. To ensure the reliability of the system, on the anti-interference aspects, the software design also takes the following measures: (1) digital filter: to average filter the collected data for protection from pulse interference. That is to sort the continuous sampling of a few data, removing one of the largest and the smallest, and then averaging the remaining data. In addition, do the differential identification for the size of the data. (2) embedded in the routines several "RST" commands, which allow PC pointer to point the beginning of the program 2080H; in all program modules, to plus several "NOP" instructions in front of the important test instructions, the jump instructions and the call instructions. (3) In addition to the hardware watchdog, microcontroller software watchdog function also is used. (4) Main components, important parameters (such as battery voltage, motor current, etc.), as well as important storage units must be real-time tested to determine whether the working condition is normal. (5) To cure the system's basic parameters to the EPROM.

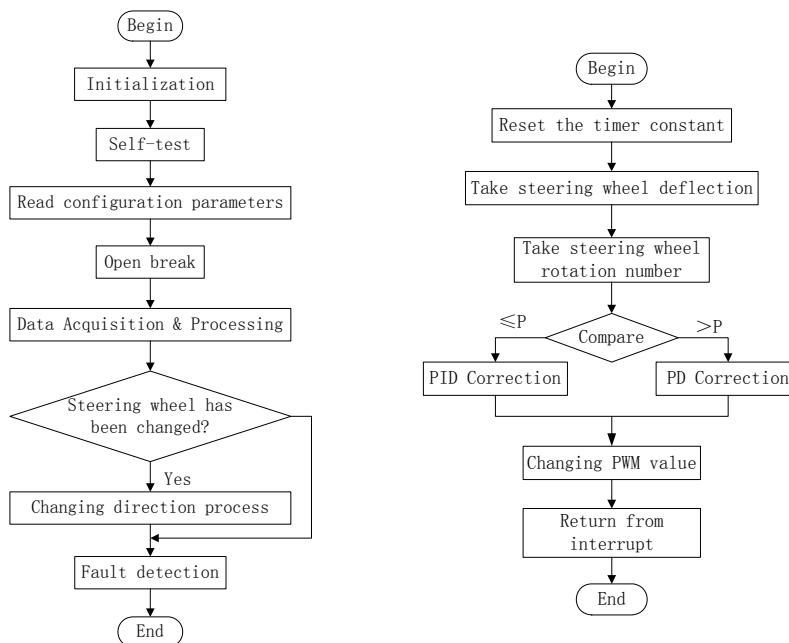


Fig. 5. (a)The main program flow chart, (b) Timing PID correction and the output interrupt service program of the PWM

6. Conclusions

This controller and electric power steering system have already been on trial and improved. The power effect is remarkable and hand feeling is good. At current, we are completing the program and debugging of the fault diagnosis.

Acknowledgements

At present, we have finished preliminary experiments in the automobile experiment bench and the real car of Changhe Suzuki (Liana). Fund: Harbin Municipal Fund(Z02944)

References

- [1] Nakayama T, Suda E. The present and future of electric power steering. *Int J of Vehicle design* 1994 ;15:243–254.
- [2] Yasuo Shimizu, Toshitake Kawai. Development of electric power Steering. SAE 91U14.
- [3] Badawy A, Bolourchi F, Gaut S. E-Steer TM system redefines steering technology. *Automotive Engineering*, 1997 1U5(9):15-18.
- [4] J. Kim, J. Song, Control logic for an electric power steering system using assist motor, *Mechatronics* 12, 2002.
- [5] O. Moseler, R. Isermann, "Application of Model-Based Fault Detection to a Brushless DC Motor", *IEEE Transactions On Industrial Electronics*, 2000.
- [6] O. Moseler, R. Isermann, "Model-Based Fault Detection for a Brushless DC Motor Using Parameter Estimation", *IEEE*, 1998.
- [7] R. Isermann, Model-Based Fault Detection and Diagnosis-Status and Applications, *International Federation of Automatic Control*, v.29 no.1, pp.71-85, 2005.
- [8] R. McCann, "Variable Effort Steering for Vehicle Stability Enhancement Using an Electric Power Steering System", *SAE*, 2000.
- [9] Y. Lee, "A Study on Development of an Electronic Control Unit and a Fault Detection Algorithm for a Motor Driven Steering Column", *Hanyang University*, 1998.
- [10] A.T. Zaremba, M.K. Liubakka, R.M. Stuntz, Control and Steering Feel Issues in the Design of an Electric Power Steering System, *Proceedings of the American Control Conference*, 1998.